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Evaluation of Strike Group Defender as a training platform

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EVALUATION OF STRIKE GROUP DEFENDER AS A TRAINING PLATFORM

by

Perry L. McDowell

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The MOVES Institute at the Naval Postgraduate School performed an evaluation of Strike Group Defender (SGD) at the behest of Office of Naval Research. MOVES personnel applied science of learning principles to SGD to determine its potential use as a training tool for anti-ship missile defense. The results were positive, with SGD having many of the characteristics that produce effective training simulations and games. We recommend that SGD receive a full training effectiveness evaluation or transfer of training study to verify that SGD actually delivers the anticipated results.

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ABSTRACT

The MOVES Institute at the Naval Postgraduate School performed an evaluation of Strike Group Defender (SGD) at the behest of Office of Naval Research. MOVES personnel applied science of learning principles to SGD to determine its potential use as a training tool for anti-ship missile defense. The results were positive, with SGD having many of the characteristics that produce effective training simulations and games. We recommend that SGD receive a full training effectiveness evaluation or transfer of training study to verify that SGD actually delivers the anticipated results.

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I. EXECUTIVE SUMMARY

A. OVERVIEW

The MOVES Institute at the Naval Postgraduate School performed an evaluation of Strike Group Defender at the behest of Office of Naval Research. SGD is an ambitious undertaking designed to support the Commander, Fleet Forces Command's (CFFC) number one priority: defeating anti-ship cruise missiles (ASCMs). The SGD project centers on a game of the same name which trains players by allowing them to defend U.S. Navy ships against incoming cruise missiles. However, it is much more than that.

(**NOTE:** In order to avoid confusion between the overarching framework and the game, throughout this paper, we will refer to the framework as "Strike Group Defender- Service Platform" (SGDSP), while we will refer to the game as "Strike Group Defender – Game" (SGDG).)

SGD is a ubiquitous interactive training "ecosystem" designed to advance warfighter performance by giving Naval personnel[1] familiarity with a subset of the basic concepts and phenomenology of electromagnetic maneuver warfare (EMW). This subset includes electronic warfare (EW) ASCM soft-kill systems and tactics to counter emerging ASCM threats.

However, its developers designed SGD to improve ASCM defense via an additional mean besides training. Although this is not as fully developed as the training portion, designers envision using SGD to as a virtual demo space to conduct analytical analysis of data derived from players. This would allow the Navy to measure with great

[1] Although the game would be useful for anyone who wants to learn more about ASCM defense, such as Sailors studying for their Enlisted Surface Warfare Specialist qualification, the primary expected users are those who stand watch in the combat information center (CIC) of a ship (such as tactical action officers, CIC watch officers, and Sailors in the FC/CTT/OS ratings), and those who serve on battle group staffs involved in anti-air warfare.

granularity performance and trends at the individual and aggregate level and use SGD to crowdsource new ideas in combating ASCMs, EMW and other possible disciplines.

B. RESPONSIBLE ORGANIZATIONS

Several groups worked together to create SGD. The Office of Naval Research (ONR) (PMR-51) created the concept and oversaw development. The Massachusetts Institute of Technology's (MIT) Lincoln Labs, Air and Missile Defense Technology Division, was the prime contractor and investigated, developed, and prototyped advanced sensor, EW, and decision support technologies which they delivered to the game developers. MetaTeq, Inc. served as the program technical and management lead and Pipeworks Inc was the lead developer and designed the game and web infrastructure for SGD in concert with the other commercial groups and expertise. Commander, Third Fleet, N3, involved at the outset, was instrumental in helping delineate Navy training requirements and managing Fleet participation in the prototype testing and evaluation.

C. SGD

SGD consists of the browser-based game of the same name and the associated web infrastructure. The game serves four main purposes. The first is as a training tool, which introduces the players to the different types of missile threats and the countermeasures which defeat them. The second purpose is to provide an environment where the player can put this knowledge into practice, repeatedly, by playing as the "blue," or U.S. player. The third is providing methods where the player can employ higher levels of thought. The game offers two mechanisms for this: by allowing the player to play as the "red," or enemy, player launching missiles at blue forces, and by developing scenarios for others to play. Each of these allows development of deeper understand of the material, which is key to developing expertise. (Dreyfus & Dreyfus, 1980). Finally, it is the enticement that initially draws people to the SGD website.

While the game makes up the center of SGD, it contains many other components which support its goals. Visible to the players are the forums, where players can conduct conversations about the game or other topics. Invisible to the players are the underlying analytical tools, which allow developers to analyze data gathered from players. Metateq and Pipeworks used their experience in creating many different web-based commercial

games and a 9 years' history in DoD serious games to build the framework so that it can save almost any type of player data. Developers can use this data to improve the players' experience with the game or to glean information on which tactics worked best and warrant further investigation for efficacy using higher fidelity simulations.

D. SGD EVALUATION METHODS

Over a ten-month period, MOVES Institute personnel performed an in-depth examination of SGD. This included extensive play testing of the game, assessment of the other features of SGD, and frequent interaction with the design team in order to evaluate their processes and to understand the learning elements. The evaluator's area of expertise is in game-based training, especially for Naval surface forces, so the evaluation focuses on the training aspect of SGD. However, he does have experience in the other potential uses of SGD and comments on them, but he is not considered an expert in those areas.

Additionally, in order to make strongly substantiated claims upon the training effectiveness of any training method, it is required to perform a training effectiveness evaluation (TEE) upon the method. Therefore, this report does not claim to prove that SGD is an effective training device. Instead, it looks at SGD's traits and compares them to those of other training methods that are widely considered effective, and examines how SGD stacks up against them. However, due to the significant cost in time, funds and resources, the military rarely performs TEE's on ANY type of trainer, and the lack of a TEE for SGD should not be considered a reflection upon it.

E. SGD EVALUATION RESULTS

1. Training

The evaluation of SGD's training is extremely positive and we expect to be an effective training tool. We believe this for several reasons. The primary reason is that it adheres to several methods generally considered to produce effective training, such as:

- Utilizing active learning as opposed to passive
- Scaffolding
- Repetition
- Opportunity for reflection and higher-order cognition
- Challenging learners at appropriate levels
- Simplicity of interface to minimize extraneous processing
- Authenticity at an appropriate level
- Community of learning

Another reason we feel that way is somewhat similar, but on a wider scale. One of the leaders in the academic study of games for training, James Paul Gee, posits thirty-six principles that training games should follow, and that the most effective training games meet more of these principles. SGD meets twenty-five of the thirty-six, a very high number**.**

Additionally, the success of SGD at a serious games competition bodes well for its success. The Serious Game Showcase and Challenge (SGS&C) is a competition held yearly at the Interservice/Industry Training, Simulation and Education Conference (I/ITSEC), the premier gathering for the international military training community. Dozens of judges evaluate serious games submitted by developers from across the globe. These evaluators are experts in their varied fields, which include gaming, training, military, and academia. SGD won as the "Best Game, Government" at the 2014 SGS&C and received uncommonly rave reviews from the evaluators. This demonstrates the quality and effectiveness of SGD, given that such a large and diverse panel rated the game so highly.

2. Technologies and Future Use

The developers designed SGD to promote both analytical analysis of user performance and crowdsourcing of ideas, both of which expand the value of SGD far beyond training.

Metateq and Pipeworks, the game companies that designed the overall SGD system, have already built several commercial games that evaluate the play of massive numbers of players. Its employees used the skill they gained by designing game infrastructures to allow easy recovery and analysis of this data when designing SGD. Thus, it is easy to record and track almost any piece of data – down to each of the player's "clicks." This capability is central in the ability to perform the type of detailed analysis necessary to extract crowdsource data that the Navy can use to develop new tactics, techniques and procedures in ASCM defense. It is critical that the designers plan the game framework for such data extraction before building, as it is very difficult to add this capability later.

Lastly, the architecture or "ecosystem" of SGD is content agnostic, meaning it can support a wide array of other naval disciplines or warfare areas in both training and operational wargaming. Designers built content additions using an "app-like" convention. The S&T/R&D investment and "long game" that ONR and MIT LL conceived for SGD is to build a platform that is built last, simultaneously support ASCM and EMW, as well as a try to establish a new technological innovation for future virtual and constructive training and wargaming.

F. RECOMMENDATIONS

We recommend the Navy take advantage of this advancement in technology and training consistent with the recommendations being developed and put forward by the Navy Warfare Development Command (CNO's designated lead for EMW). In the near term, SGD offers immediate advances to the efficacy of current Navy schoolhouse and Fleet ASMD training and an unprecedented, scalable, virtual demo space for distributed war gaming and TTP development and demonstration available to general Fleet users."

Additionally, we urge policy makers to continue the development of SGD by expanding it to include a classified version, allowing a different level of instruction. The current unclassified version can only teach the basics of ASMD, while a classified version would allow trainers to expand their use of SGD to include training more advanced techniques, tactics, and procedures.

II. INTRODUCTION

This paper presents an investigation into Strike Group Defender (SGD) by the MOVES Institute at the Naval Postgraduate School. It follows the framework used in the multiple game reviews in (Hussain & Coleman, 2015). This simple but effective model examines games by:

- inspecting the context of the game;
- discussing the game elements;
- analyzing how the game performs those elements, including how it presents the learning;
- providing a final discussion on the overall merits of the game.

A. CONTEXT

Strike Group Defender is a project created by the Office of Naval Research Integrated Air and Missile Defense (IAMD) Future Naval Capabilities (FNC) portfolio managed by PMR-51. SGD is an ambitious undertaking designed to support the Commander, Fleet Forces Command's (CFFC) number one priority: defeating anti-ship cruise missiles (ASCMs). The SGD project is centered on a game of the same name which trains players by allowing them to defend U.S. Navy ships against incoming cruise missiles. However, it is much more than that.

(**NOTE:** In order to avoid confusion between the overarching framework and the game, throughout this paper we will refer to the framework as "Strike Group Defender" and abbreviated as "SGD," while we will refer to the game as "Strike Group Defender – Game," abbreviated as "SGDG.")

SGDG falls into the category of "serious games." Serious games are those which developers create for reasons other than pure entertainment. These other reasons can be many and varied, such as advertising, political persuasion, problem solving, even improving the players' health. However, the most common form of serious game is the game created for training or education, which is where SGDG falls.

Scott Orosz, the program manager for SGD said, "Strike Group Defender is an affordable, realistic way for personnel to understand and emulate the capabilities being developed in the IAMD FNC's and learn how those improvements enhance the means to respond to threats Navy ships face around the world. But beyond that application, this technology will allow Sailors and Marines to plan, experiment and train whenever they want, whether they are at sea or in a classroom." (Beidel, 2015)

SGD includes analytics, crowdsourcing, social media and cloud technology to enhance the effects of the game. While the training that Sailors receive by playing the game is highly effective, these other areas means that the game does more than merely provide the training received during the game. It indicates that SGD can give the Navy valuable insights into the tactics, techniques, and procedures (TTPs) which can enhance the ships' capabilities against ASCMs. Thus, the game not only teaches the players how to defeat this threat, but the players' actions may suggest to the Navy new and better ways to do so.

1. Background

SGD trains Sailors in electromagnetic maneuver warfare (EMW). VADM Ted Branch, Deputy Chief of Naval Operations for Information Dominance (N2/N6), defined EMW as:

> "EMMW[2] is an operational approach to seizing the initiative across the electromagnetic spectrum (EMS). The goal is to combine EMMW capabilities in the sea, air and land domains to generate enhanced combat effects. EMMW, in essence, means leveraging the cyberspace domain and the full electromagnetic spectrum for both offensive and defensive effects.

[2] NOTE: In this quote, VADM Branch used the acronym "EMMW," which was the acronym for "electromagnetic spectrum maneuver warfare," the approved nomenclature at the time. While the Navy has since modified the term to "electromagnetic maneuver warfare (EMW)," the two are essentially identical.

EMMW is not a program, or system, or even a refined concept of operations. It is an emerging operational art, one we must master to fully understand the battlespace. We must then use that awareness to better employ our own forces while altering the enemy's perception of the battlespace and minimizing his freedom of maneuver within it." (Branch, 2013)

EMMW is concerned with all sorts of electronics communications, including protecting our computer networks, infiltrating and attacking the enemy's networks, and other aspects of what most commonly refer to as "cyber-warfare." SGD covers on a subset of EMMW that focuses on ASCM defense using what the Navy has traditionally considered parts of electronic warfare: electronic support (ES, previously known as electronic support measures, or ESM) and electronic attack (EA, previously known as electronic counter measures, or ECM).

The Chief of Naval Operations, ADM Jonathan Greenert, has made this a high priority for the Navy. "We're using the electromagnetic spectrum as a domain and as a means, and we understand and grasp it," said Greenert. "We have to figure out how we can beat things electronically first. Why do we spend all this money kinetically if we can jam, spoof or do otherwise?" (Metzger, 2013)

The Navy refers to this type of missile defense as a "soft-kill," as opposed to "hard-kill" options that involve hitting the ASCM with projectiles of some sort, such as surface-to-air missiles or rounds from a gun. Traditionally, Navy anti-air warfare (AAW) has centered on hard-kill options, primarily surface to air missiles. Sailors and officers viewed soft-kill as a backup, much like the Phalanx Close-in Weapon System (CIWS); these were safety nets used if the primary defense against incoming missiles of hitting them with a ship's own missiles failed.

Designers built SGD to support specific fleet requirements:

- Support the CFFC #1 priority – defeating anti-ship cruise missiles
- Respond to the CNO's call to generate forward thinking and solutions in EMW
- Advance MIT and Navy efforts in next generation evolution of EW Red/Blue simulation
- Improve the effectiveness of sailors EW systems employment in an anti-ship missile defense (ASMD) environment

- Augment existing fleet training with a realistic live/virtual training environment emphasizing war fighting in dense, contested, and degraded ASMD scenarios against near-peer adversaries.

2. Technical Objectives for SGD

PMR-51 listed five technical objectives for the SGD project. The technology and architecture must:

- Act as an extension of existing training for trainers and trainees and pick up where training stops, whenever and wherever they are connected
- Remain system agnostic and support existing EW continuum efforts
- Be compelling and competitive. Sailors must want to train with it on duty -- and "play" with it off-watch
- Target cognitive and experiential skills to enhance warfighter performance across all systems and scenarios
- Design analytics and big data analysis that extracts best behaviors and applies them in game play for other players (PMR-51 and MIT Lincoln Laboratory, 2014)

3. Usage Statistics

ONR released SGD for trial usage on October 1, 2014. Commander, Third Fleet sent a message to all units informing them of SGD's availability and urging them to utilize it. In the six months since, 199 users registered for SGD, and made 2759 visits to SGD. These users were from 28 Navy units.

4. Classification

Most of the material covered by SGD is classified, some at very high levels. However, the developers decided to keep everything in SGD at an unclassified level and for official use only (FOUO). This gives personnel much greater access to the system, since users do not need to be on a secure computer in a secure space to access it. Generally, there are more unsecure computers than secure ones; users can even use their personal computers to interact with SGD.

To allow the system to remain unclassified, all missiles and countermeasures are notional, and given fictional names. Additionally, the underlying performance measures the system uses to conduct gameplay are also notional and abstracted from the original algorithms created by the MIT's Lincoln Labs, Air and Missile Defense Technology Division. Although the data is unclassified, it is still realistic enough to provide useful training.

Because the game is FOUO, players are required to sign up for SGD using a ".mil" e-mail address. This prevents unauthorized users from gaining access to the FOUO information in SGD.

PMR-51 has design plans to creating a secure version of SGD to be used in concert with the unclassified version. SGD was designed so that creating a classified version would be fairly simple. Instead of hard coding the data regarding missiles and countermeasures into the game, the game references separate data files for all that information. Replacing the current files containing notional data with others containing the actual, classified data creates a classified version of the game.

B. GAME ELEMENTS

We begin by discussing the important elements of SGDG. The information in this section forms the basis for the findings in the analysis section, which follows.

1. Learning the Game

When a player enters SGDG, it presents him with a screen as shown in Figure 1, from which he will chose what to do on this visit. It is a simple and easy-to-use interface that allows new players to intuitively infer what they need to do to proceed, yet straightforwardly allows experienced players to quickly perform whatever action they would like.

The far left (element "1" in Figure 1) has buttons which allow the player to switch between the game and the forum, report bugs or make suggestions to the development team.

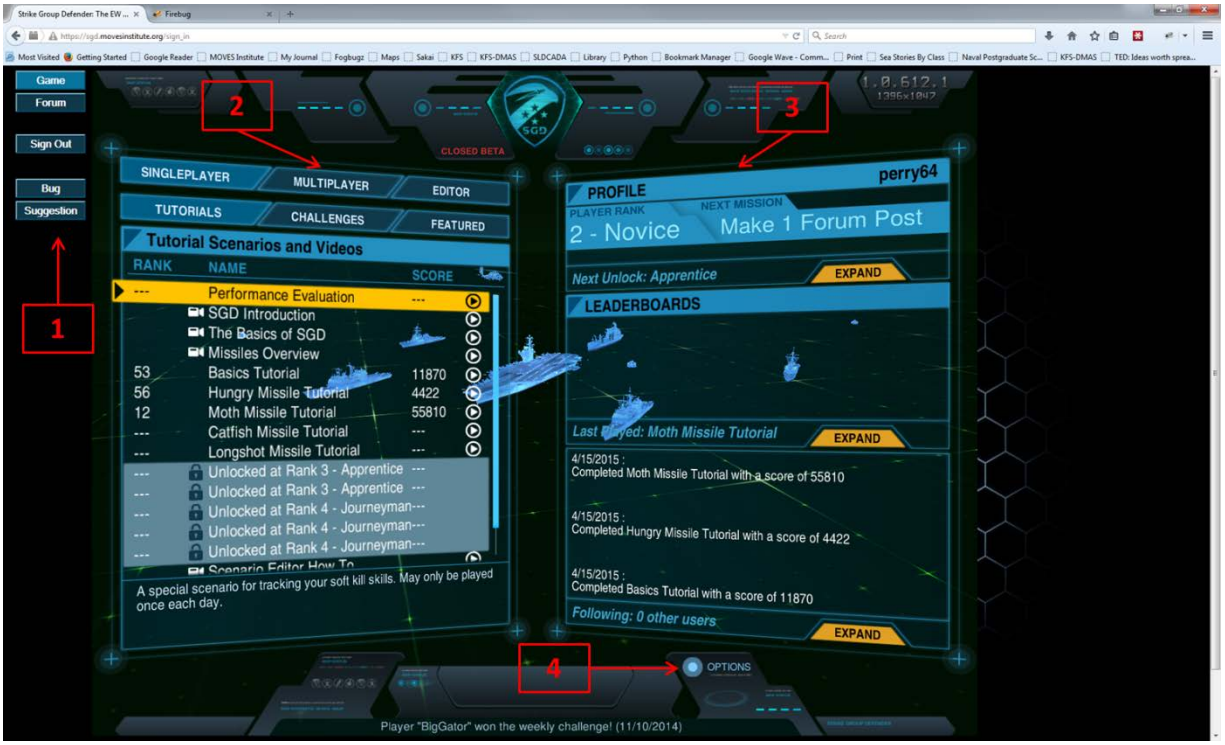

Figure 1. Entry screen for SGD

The left half of the screen displays the menus where the player interfaces with the game elements. The topmost menu (2) allows the user to switch between different modes: single-player, multiplayer, or scenario editing; the sub-menus beneath change depending upon the mode selected.

The right half of the screen is the player's profile (3). This shows his rank, next mission, the leaderboard of the scenario he has selected in the menu area, and a list of his recent activities on the site. The "Options" button (4) allows the player to control volume, modify keyboard controls, and change his password.

The first time a player opens the game, the game reduces the options available, which simplifies his path. The only options are to play the "SGD Basics" tutorial or watch one of three videos: "SGD Introduction," "The Basics of SGD," or "Missiles Overview." Once the player gains proficiency in the basics of the game, the game makes available tutorials on the simplest types of missiles.

Each of the next group of tutorials is missile-specific. Each begins by briefing describes the missile's homing mechanism and how to defeat it. The tutorials reduce the

player's choices by only giving the player the correct countermeasures to defeat the missile, so she doesn't need to waste mental processing deciding on what to do. He only needs to think about how to use the countermeasure properly.

After the player completes those with passing scores, the game unlocks more missile tutorials. Thus, the game steps the player through slowly and ensures that the player has the knowledge and skills required before allowing him to move to a more advanced scenario. As the player demonstrates competency in the various skills, he advances in rank within the game. Additionally, the game makes very clear what is needed to advance to the next higher rank – both the current rank and the requirement to advance are shown at the top of the user profile on the left side of Figure 1. Leading the player along in this manner ensures that the player has the skills necessary for the next stages of instruction and prevents frustration which can lead to abandoning the game.

Leading the player via these methods also serves as the means to get players involved in the players to the larger SGD ecosystem. Besides requiring performance in the tutorials to advance in rank, players must also participate in various aspects of SGD's media and content creation. These tasks include making a forum posts, liking another player's post, following another player, creating a scenario and releasing it for others to use. Doing this leads the player into areas of the SGD ecosystem that he likely would not come across on his own.

C. GAMEPLAY

While there are both single-player and multi-player options to the game, early gameplay is all single-player. In fact, SGDG does not enable multi-player gameplay until after the player has demonstrated a significant proficiency at single-player scenarios.

1. Single-Player

Like many good games, the gameplay is simple to describe, but difficult to perform effectively. The player serves as commander over a number of U.S. Navy ships from one of the four classes shown in Figure 2. The cruiser and destroyer classes contain different types of defensive measures against incoming missiles – one hard-kill weapon, a surface to air missile, and eight soft-kill countermeasures.

Figure 2 U.S. Ships in SGDG

Each scenario is designed so that various types of incoming missiles target the U.S. ships. While players can launch defensive missiles against any type of incoming missile, each soft-kill method is only effective against certain types of missile homing systems. Figure 3 shows the different types of incoming missiles and countermeasures in SGDG.

Figure 3 Missile Matrix

The player's goal is to prevent missiles from hitting U.S. vessels by using these defensive measures. As mentioned, simple in theory, hard in practice once the number and types of incoming missiles rise. The scenario has limited amounts of each type of countermeasure for the player to employ, and some of the countermeasures last for only limited times. For example, infrared (IR) flares last for only 25 seconds; if a player launches one to distract an IR-homing missile, if the flare goes out before the missile passes the ship, it searches for another IR signature to home in on and might reacquire the ship. Likewise, the geometry between the ship, the decoy and the incoming missile affects the likelihood the missile is decoyed, so the player must constantly be working to maximize this relationship. Unfortunately, even if a player has created an optimum defensive scheme, incoming missiles can continue to appear. These new threats might force him to take actions to defeat the new missiles which adversely affect his previously perfect plan.

Once all the missiles either hit or miss the ships, the scenario is complete and generates a report giving the number/type of missiles, whether they hit the ships, and if not, how the player defeated them. SGDG uses this information to create a score. Although other factors, such as how well the player conserved resources, contribute to the score, the biggest factors are whether the incoming missile hits a ship ("HIT" = -5000 points), is shot down by a missile ("HARD KILLED" = 0 points), or is distracted by a countermeasure ("SOFT KILLED" = 10000 points). The player's performance is recorded by SGD.

2. Multi-Player

Designers added a multi-player variant of the game to provide additional training value by presenting the battle in a different perspective for the trainees. Multi-player allows players to play either in a defensive role as "blue" forces (U.S. Navy) or in an offensive role as "red" forces. To join a multi-player game, a player goes to a game lobby to see if anyone has proposed conducting a multi-player game. If another player has done so, she may join; otherwise she may propose her own game and wait for another player to join.

Trainees playing as blue forces essentially play the single-player game, with the only difference being that there might be multiple blue players. In this case, they can divide responsibility so that each is either responsible for different ships or different types of countermeasures. As in the single-player game, blue must defeat missiles launched by red.

The players controlling red forces have a completely different game play. Instead of being in the center and looking out, as blue forces do, the red player is on the periphery of the battle space looking in at the blue forces. In addition, instead of seeing the blue forces as ships as they would appear visually, red players see what the blue forces emit, such as heat (IR) or signal emission (EM), or how they look in response to radar, which is called their radar cross section (RCS). In actual combat, this information only provides an approximate location, so the interface presents it as clouds, shown in Figure 4. This adds ambiguity, because the player cannot be certain of the actual locations of the blue forces for missile targeting. This is realistic for conducting over the horizon targeting of surface ships without the actual positions being relayed from another platform.

Scenario designers place one of two constraints on the red player: she has either a limited amount of missiles available to fire, or a limited amount of funds to purchase missiles to fire at blue. During gameplay, the red player chooses when to fire her missiles, from which direction, and at what location. After red fires all her missiles and blue has either defeated them or been hit by them, the game concludes.

The game uses the same point system as the single-player. When designing the scenario, the designer estimates a target score that blue is expected to score if both players perform averagely. If blue scores above this score, it did better and wins, while if red keeps blue below it, red wins.

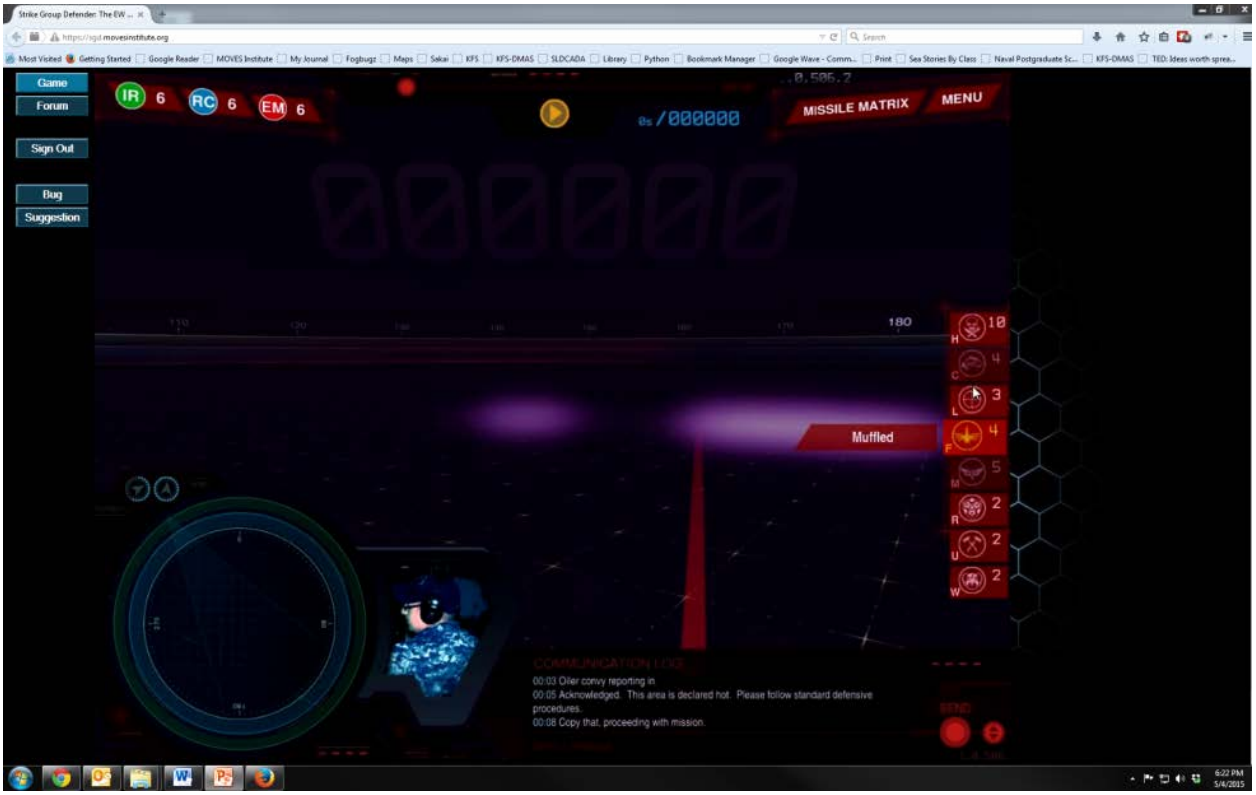

Figure 4 Red Player's RCS View

D. GAME INTERFACE

1. Game Introduction

Once the player selects a scenario, a briefing screen appears, as shown in Figure 5. This screen displays the briefing for the scenario. In the tutorials, the briefing consists primarily of hints, but in more advanced scenarios developers would include the basic information that naval exercise planners normally provide, such as friendly force composition, expected enemy threat, atmospheric conditions and the like.

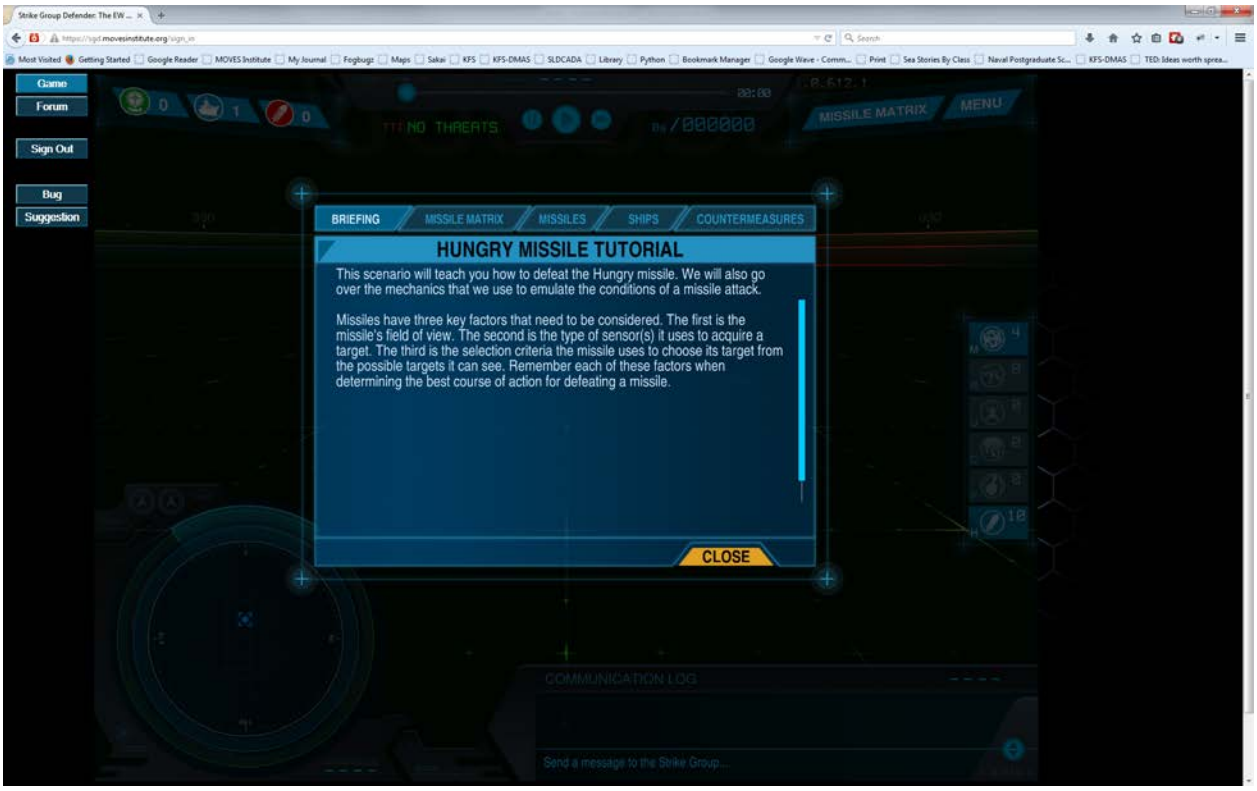

Figure 5 Hungry Missile Tutorial Briefing Screen

From this screen, the player can also access the list of missiles, the list of ships, the list of countermeasures, and the missile matrix shown in Figure 3. The lists contain all the types of missiles, ships and countermeasures in the game, as well as a brief description of each. In the missile matrix, shown in Figure 3, each of the ten rows represents a missile, while each of the nine columns represents an anti-missile defense. The cells of the resulting matrix contain the effectiveness of a given defense versus a missile. For example, an IR decoy (the first column in Figure 3) has 90% effectiveness against a "Moth" missile, 10% against a "Catfish" missile, and 60% against a "Cerberus" missile and has no effect upon any other type of missile. The values are color-coded to make determining the effectiveness of a countermeasure at a glance easier.

2. Blue Player

After reading all the material on the introduction screen, the blue player closes it and the game begins with the player looking at the game interface screen shown in Figure 6. When the scenario begins, the player can only see his own ship (1) and the countermeasures menu (2), which also displays an inventory of each countermeasure.

The player can rotate the view using the right mouse button, zoom using the scroll wheel and center the view on a ship by clicking on it.

Figure 6 SGDG Interface

In order to launch a countermeasure, the player clicks on one of the countermeasures in the countermeasures menu and then clicks where he wants it deployed. Players can select an incoming missile by clicking on it, and move between incoming missiles by pressing the space bar. To fire perform a hard-kill, the player selects an incoming missile, and clicks on the "HARDKILL (H)" option on the countermeasures menu. There are also hot key controls for each of these commands.

If the player launches a countermeasure, it will show up in blue on the game screen (3). Missiles are in red (4), and their type is identified on the screen (5, showing that this is a "HUNGRY" missile). The display shows the missile's path (6), allowing the player to determine whether it is targeting a ship or a countermeasure.

This very simple interface gives the player the power to perform all the needed actions while only needing to remember a few simple actions.

3. Red Player

There are two modes of playing as the red player – she has either a set number of missiles to fire, or a set amount of funds. We will describe the former mode first.

After reading all the material on the introduction screen, the blue player closes it and the game begins with the player looking at the game interface screen shown in Figure 7. As mentioned earlier, the red player doesn't see actual ships, but a representation of what the blue forces emit, such as heat (IR) or signal emission (EM), or how they look in response to radar, which is called their radar cross section (RCS). The player switches between the views by clicking on the desired view icon (1). Doing this highlights all the missiles the missile inventory menu (2) which use that homing type. Selecting a missile type from also switches the view into the type of sensor that missile uses selected. The red player can change the direction from which she looks views the scene by using the right mouse button to rotate the view. If a missile type is currently selected, a red line will appear (3), showing the target the missile will home in on at launch. Once the red player is satisfied with the launch setup, she clicks on the missile icon to launch the missile.

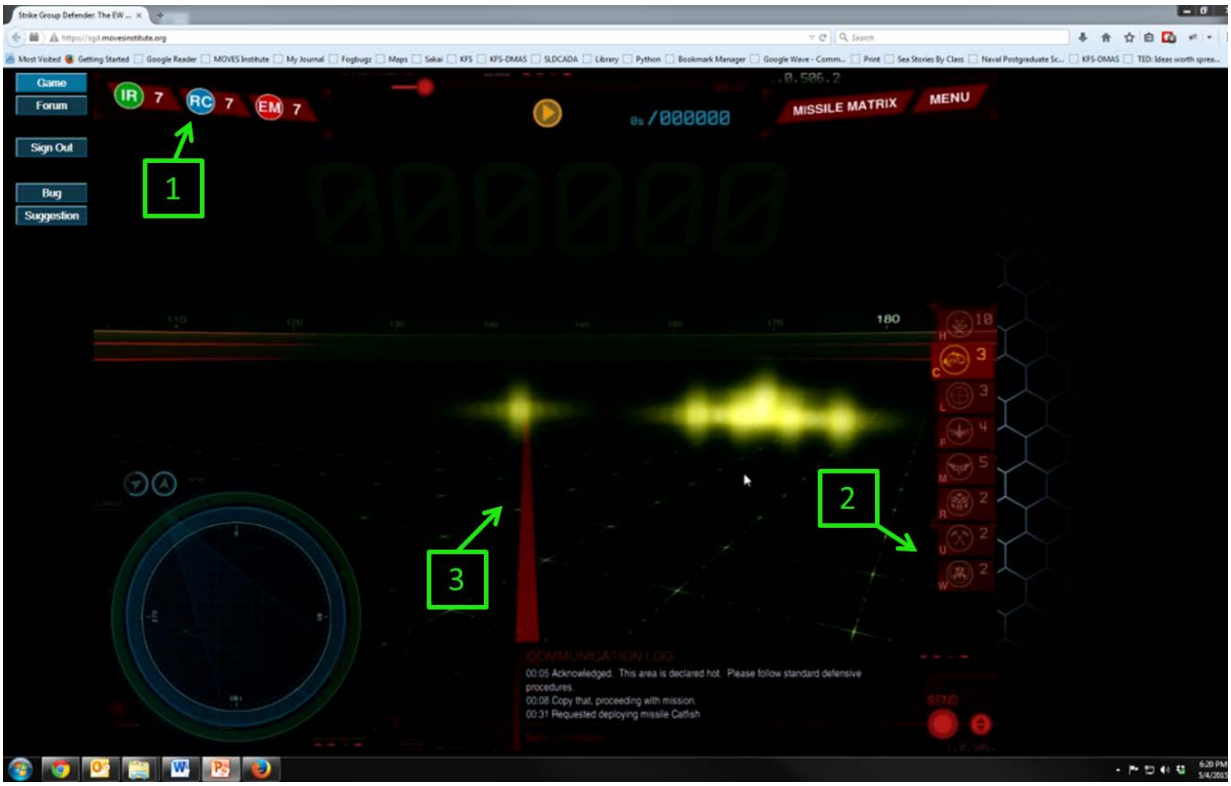

Figure 7 Red Player User Interface

If the scenario gives the player a given amount of funds, the interface, shown in Figure 8, has only two differences from the normal type of control. At the top of the screen, the interface shows the amount of funds the red player has for the scenario (1). The starting amount is different for each scenario, and the amount is updated as the red player expends funds by firing missiles. On the missile menu, instead of an inventory of missile, the interface shows the cost of each (2). In order to prevent firing a barrage of the same type of missiles simultaneously, which is a very effective tactic, the cost of firing the just launched missile type rises sharply, and then begins to decrease until it reaches the base cost. This is reflected in the price on the missile menu.

Again, this is a very simple interface while requiring the player to remember only a few actions to perform advanced operations.

Figure 8 Red Player Monetary Interface

III. ANALYSIS

A. SGD EVALUATION METHODS

Over a ten-month period, MOVES Institute personnel performed an in-depth examination of SGD. This included extensive play testing of the game, assessment of the other features of SGD, and frequent interaction with the design team in order to evaluate their processes and to understand the learning elements. The evaluator's area of expertise is in game-based training, especially for Naval surface forces, so the evaluation focuses on the training aspect of SGD. However, he does have experience in the other potential uses of SGD and comments on them, but he is not considered an expert in those areas.

Additionally, in order to make strongly substantiated claims upon the training effectiveness of any training method, it is required to perform a training effectiveness evaluation (TEE) upon the method. Therefore, this report does not claim to prove that SGD is an effective training device. Instead, it looks at SGD's traits and compares them to those of other training methods that are widely considered effective, and examines how it stacks up against them. However, due to the significant cost in time, funds and resources, the military rarely performs TEE's on any type of trainer, and the lack of a TEE for SGD should not be considered a reflection upon it.

As we studied SGD, we looked for many principles or features that are characteristic of effective training systems. Some of these are unique to games, such as the degree of authenticity, while others can be found in any type of learning system, such as active learning and repetition. Our belief is that finding several such features indicates that SGD has a high likelihood of providing effecting training.

B. LEARNING PRINCIPLES

Principle: Active Learning
Discussion: Active learning is a process whereby students engage in activities that promote analysis, synthesis, and evaluation of learning content. It also places the responsibility for learning on the learning, rather than the trainer or the system. By

forcing the trainee to be engaged in the process, it increases the likelihood that the learner will retain the material (Prince, 2004). (Bonwell & Eison, 1991).
Demonstrated in SGD: Like almost every game for training, active learning dominates SGD. Very little, other than the introductory videos, is passive. Even the simplest of tutorials require the trainee to take an active part in order to progress.

Principle: Scaffolding
Discussion: Scaffolding refers to a variety of instructional techniques used to move students progressively toward stronger understanding of the concepts involved (Hammond & Gibbons, 2005).
Demonstrated in SGD: During the tutorials of SGDG, the only countermeasure options available to the player were those required to complete the task. By removing all extraneous choices, the player did not have to consider which countermeasure to use, but could focus exclusively on how to deploy the correct countermeasure properly.

Principle: Red Teaming
Discussion: Often, playing from the point-of-view of one's opponent gives insights that are not apparent from one's normal point-of-view.
Demonstrated in SGD: The red team component of SGD gives a trainee the capability to play as the opponent, giving her the ability to observe the effects of the blue players' actions. By seeing how blue's actions appear to red and affects red's actions, she can better tailor her actions in the real world.

Principle: Content Creation

Discussion: Creating content forces trainees to think at a deeper level about the capabilities of various assets. Doing this is a good way to move along the path to expertise as described by (Dreyfus & Dreyfus, 1980).
Demonstrated in SGD: There is a scenario generator that players can use to create content and share it with other players.

Principle: Repetition
Discussion: Repetition is important in developing any skill – one of the oldest training axioms is "Practice makes perfect." (Weibell, 2001) calls it "perhaps the most intuitive principle of learning" and mentions Aristotle's comments on its role in learning. As scientists have gained the ability to observe the brain in action, we have learned that repetition strengthens the neural pathways in the brain, which allows easier retrieval – i.e., learning.
Demonstrated in SGD: SGD provides significant opportunity for repetition. It forces the trainee to repeat tutorials until he demonstrates an acceptable standard of performance. It provides a daily scenario, which urges the trainee to return daily to maintain competency. Additionally, most scenarios are very short, on the order of two to five minutes, which allows trainees to play them multiple times.

Principle: Challenge
Discussion: Challenge drives trainees to initially engage learners to start learning a task and to encourage learners who are reluctant to start to learn content.
Demonstrated in SGD: In SGDG, trainees need to master several skill sets in order to advance in the game. The trainee's motivation to advance and do well in the game translates into motivation to learn the material.

Principle: Community
Discussion: Advances in distance learning have shown that a sense of belonging to a community greatly enhances the likelihood that a student will complete the course.
Demonstrated in SGD: SGD has robust forums. In addition, SGD leads users into joining the forums and becoming active members by requiring them to make a post, follow another user, and "like" a post in order to advance levels.

Principle: Simplicity of Interfaces
Discussion: Interfaces for games, and training games in particular, need to be simple. The primary reason for this is that learning requires brainpower, people have finite brainpower, and any brainpower devoted to a complicated interface reduces that available to play the game and learn the material. (Mayer, 2010) defines three types of processing that learners perform when learning a new task: • Essential processing – this is the processing required to complete the task, in this case, defend the ship against missile attack. • Generative processing – this is the processing the brain uses to think about how it is performing the task, almost a form of meta-cognition. Mayer posits that this processing is key to produce learning. • Extraneous processing – this is the processing required for any other items, such as using the interface. As shown in Figure 9, the trainee's mental capacity is finite. The task determines the amount of essential processing required and cannot be changed. In order to complete the task, the user must perform whatever extraneous processing, but that the developers determine that by how simple their interface is. Whatever remains is how much the user can allocate to generative processing. As shown, we desire the extraneous processing to

be as small as possible to maximize the generative processing the trainee can devote to learning.
Demonstrated in SGD: The interfaces in SGDG were very intuitive and easy to learn. Switching between incoming missiles was as simple as clicking the space bar, controlling ship's movement was merely clicking on the ship and dragging, and most other operations required only clicking on an icon and then dragging the cursor. After a very short time, users could perform fairly advanced operations.

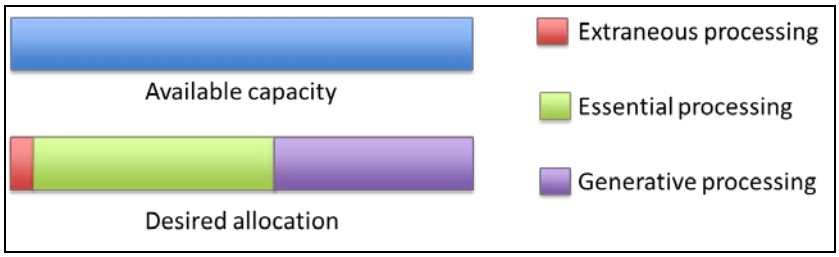

Figure 9 Mayer's Three Types of Processing

Principle: Appropriate authenticity
Discussion: Authenticity is training games involves finding a happy medium. Too much authenticity bogs the trainees down in lots of involved procedures that may not be closely related to the learning objectives. Too little, and whatever is learned has no applicability in the real world. Designers must add as much detail as necessary, but no more.
Demonstrated in SGD: We feel that SGDG maintained a nice balance. Designers built SGDG to train high level concepts of EW, so the game avoided most low-level tasks, such as "buttonology." Instead, trainees were free to focus on thinking about what to do and not how to do it. For example, trainees needed to know when it was appropriate to launch chaff, but doing so was much simpler than it would be to actually do it on a ship.

C. GEE'S LEARNING PRINCIPLES

In (Gee, 2003), James Paul Gee lists thirty-six learning principles from his study of learning in game-based environments. Some of these are generally accepted by the training community, and we discussed several of them earlier. However, while not a definitive list, Gee and others believe that successful and well-designed games follow large numbers of these. Our investigation shows that SGD meets twenty-five of these thirty-six, a large number for a game. These are (we maintained Gee's original numbering, which is why some numbers are missing):

1) Active, Critical Learning Principle

All aspects of the learning environment (including ways in which the semiotic[3] domain is designed and presented) are set up to encourage active and critical, not passive, learning

3) Semiotic Principle

Learning about and coming to appreciate interrelations within and across multiple sign systems (images, words, actions, symbols, artifacts, etc.) as a complex system is core to the learning experience

4) Semiotic Domains Principle

Leaning involves mastering, at some level, semiotic domains, and being able to participate, at some level, in the affinity group or groups connected to them.

5) Meta-level thinking about Semiotic Domain Principle

[3] Semiotic is defined as "the study of signs and symbols as elements of communicative behavior; the analysis of systems of communication, as language, gestures, or clothing." Gee's degree is in linguistics, so he tends to think more in that discipline's terms; however, considering the signs and symbols as how the trainee makes meaning from the material to be learned, it is easier to apply Gee's principals to a larger breadth of topics.

Learning involves active and critical thinking about the relationships of the semiotic domain being learned to other semiotic domains

6) "Psychosocial Moratorium" Principle

Learners can take risks in a space where real-world consequences are lowered

7) Committed Learning Principle

Learners participate in an extended engagement (lots of effort and practice) as an extension of their real-world identities in relation to a virtual identity to which they feel some commitment and a virtual world that they find compelling

9) Self-Knowledge Principle

The virtual world is constructed in such a way that learners learn not only about the domain but also about themselves and their current and potential capacities

10) Amplification of Input Principle

For a little input, learners get a lot of output

11) Achievement Principle

For learners of all levels of skill there are intrinsic rewards from the beginning, customized to each learner's level, effort, and growing mastery and signaling the learner's ongoing achievements

12) Practice Principle

Learners get lots and lots of practice in a context where the practice is not boring (i.e., in a virtual world that is compelling to learners on their own terms and where the learners experience ongoing success). They spend lots of time on task.

13) Ongoing Learning Principle

The distinction between the learner and the master is vague, since learners, thanks to the operation of the "regime of competency" principle listed next, must, at higher and higher levels, undo their routinized mastery to adapt to new or changed conditions. There are cycles of new learning, automatization, undoing automatization, and new re-organized automatization

14) "Regime of Competence" Principle

The learner gets ample opportunity to operate within, but at the outer edge of, his or her resources, so that at those points things are felt as challenging but not "Undoable"

15) Probing Principle

Learning is a cycle of probing the world (doing something); reflecting in and on this action and, on this basis, forming a hypothesis; reprobing the world to test this hypothesis; and then accepting or rethinking the hypothesis

20) Multimodal Principle

Meaning and knowledge ate built up through various modalities (images, texts, symbols, interactions, abstract design, sound, etc.), not just words

22) Intuitive Knowledge Principle

Intuitive or tacit knowledge built up in repeated practice and experience, often in association with an affinity group, counts a good deal and is honored. Not just verbal and conscious knowledge is rewarded

23) Subset Principle

Learning even at its start takes place in a (simplified) subset of the real domain

24) Incremental Principle

Learning situations are ordered in the early stages so that earlier cases lead to generalizations that are fruitful for later cases. When learners face more complex cases later, the learning space (the number and type of guess the learner can make) is constrained by the sorts of fruitful patterns or generalizations the learned has founded earlier

25) Concentrated Sample Principle

The learner sees, especially early on, many more instances of the fundamental signs and actions than should be the case in a less controlled sample. Fundamental

signs and actions are concentrated in the early stages so that learners get to practice them often and learn them well

26) Bottom-up Basic Skills Principle

Basic skills are not learned in isolation or out of context; rather, what counts as a basic skill is discovered bottom up by engaging in more and more of the game/domain or games/domains like it. Basic skills are genre elements of a given type of game/domain

27) Explicit Information On-Demand and Just-in-Time Principle

The learner is given explicit information both on-demand and just-in-time, when the learner needs it or just at the point where the information can best be understood and used in practice

28) Discovery Principle

Overt telling is kept to a well-thought-out minimum, allowing ample opportunities for the learner to experiment and make discoveries

29) Transfer Principle

Learners are given ample opportunity to practice, and support for, transferring what they have learned earlier to later problems, including problems that require adapting and transforming that earlier learning

34) Dispersed Principle

Meaning/knowledge is dispersed in the sense that the learner shares it with others outside the domain/game, some of whom the learner may rarely or never see face-to-face

35) Affinity Group Principle

Learners constitute an "affinity group," that is, a group that is bonded primarily through shared endeavors, goals, and practices and not shared race, gender, nation, ethnicity, or culture

36) Insider Principle

> The learner is an "insider," "teacher," and "producer" (not just a consumer) able to customize the learning experience and the domain/game from the beginning and throughout the experience. (Gee, 2003)

D. SERIOUS GAME SHOWCASE AND CHALLENGE

Generally, most people evaluate a commercial game by examining its critics' ratings and the awards it receives. Although critics rarely review serious games, there are still awards for them. One of the most impressive achievements in SGD's first year of distribution was winning at the 2014 Serious Game Showcase and Challenge (SGS&C). The SGS&C is a competition held yearly since 2006 at the Interservice/Industry Training, Simulation and Education Conference (I/ITSEC), the premier gathering for the international military training community. Each year, games compete for prizes in many categories, such as "Best Business Game," "Best Government Game," "Best Mobile Game," "Best Student Game," and a yearly special interest area.

Dozens of judges evaluate serious games submitted by developers from across the globe. These evaluators are experts in their varied fields, which include gaming, training, military, and academia.[4] Several evaluators rate each game in many areas, such as ease of use, game play, effectiveness as a serious game (that is, how well the game completed its non-entertainment goal), and others. The staff collates and averages scores from all the reviewers to determine the final scores for each game, and then declare the game with the best score in each category as the winner.

SGD won as the "Best Game, Government" at the 2014 SGS&C and received uncommonly rave reviews from the evaluators. This demonstrates the quality and effectiveness of the game, given that such a large and diverse panel rated the game so highly.

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[4] In the interest of full disclosure, the author has been an SGS&C evaluator for many years, and was in 2014. However, the contest is strict on potential conflict of interests, and he did not evaluate SGD because he was funded to evaluate it for ONR.

IV. OTHER CONSIDERATIONS

The developers designed SGD to promote both analytical analysis of user performance and crowdsourcing of ideas, both of which expand the value of SGD far beyond training.

Metateq and Pipeworks, the game companies that designed the overall SGD system, have already built several commercial games that evaluate the play of massive numbers of players. Its employees used the skill they gained by designing game infrastructures to allow easy recovery and analysis of this data when designing SGD. Thus, it is easy to record and track almost any piece of data – down to each of the player's "clicks." This capability is central in the ability to perform the type of detailed analysis necessary to extract crowdsource data that the Navy can use to develop new tactics, techniques and procedures in ASCM defense. It is critical that the designers plan the game framework for such data extraction before building, as it is very difficult to add this capability later.

Lastly, the architecture or "ecosystem" of SGD is content agnostic, meaning it can support a wide array of other naval disciplines or warfare areas in both training and operational wargaming. Designers built content additions using an "app-like" convention. The S&T/R&D investment and "long game" that ONR and MIT LL conceived for SGD is to build a platform that is built last, simultaneously support ASCM and EMW, as well as a try to establish a new technological innovation for future virtual and constructive training and wargaming.

V. RECOMMENDATIONS

We recommend the Navy take advantage of this advancement in technology and training consistent with the recommendations being developed and put forward by the Navy Warfare Development Command (CNO's designated lead for EMW). In the near term, SGD offers immediate advances to the efficacy of current Navy schoolhouse and Fleet ASMD training and an unprecedented, scalable, virtual demo space for distributed war gaming and TTP development and demonstration available to general Fleet users."

Additionally, we urge policy makers to continue the development of SGD by expanding it to include a classified version, allowing a different level of instruction. The current unclassified version can only teach the basics of ASMD, while a classified version would allow trainers to expand their use of SGD to include training more advanced techniques, tactics, and procedures.

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